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THE WHITE-GRUBS INJURING SUGAR CANE IN PORTO RICO

II. THE RHINOCEROS BEETLES

BY

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THE WHITE-GRUBS INJURING SUGAR CANE IN PORTO RICO.

By E. GRAYWOOD SMYTH,[1] Chief, Division of Entomology.

II.

THE RHINOCEROS BEETLES.

It has been pointed out in a previous publication that white-grubs may include the larvæ of any of the large *Scarabæd* beetles of the *Lamellicorn* family, which is divided into two tribes, the *Melolonthini* and the *Dynastini*. In the former tribe five species have been described by the writer, four in the genus *Phyllophaga* (*Lachnosterna*) and one in the genus *Phytalus*, and the habits and life-history of these have been described at length in this JOURNAL, Vol. I, Nos. 2 and 3, under the title "Life-Cycles of the May-Beetles or *Medolonthids*."

In the tribe *Dynastini* are five other species of white grubs, of which two species are considered in the present paper, both belonging to the genus *Strategus*.

THE GENUS STRATEGUS.

This includes a considerable number of species, which are widely distributed over Southern North and Central America, the West Indies, and Northern South America. There are perhaps a half dozen other species, besides the two here discussed, found in the West Indies,

[1] The unfinished condition of this paper has necessitated its being turned over to and edited by Mr. G. N. Wolcott, Mr. Smyth's successor as Chief Entomologist of the Insular Experiment Station.

none of which, however, is as widely distributed as either of these two.

All the species of *Strategus* have similar habits, living for the most part in decaying wood. Only in tropical countries, however, and especially in isolated districts or islands where the continued denudation of the native forest growth has driven them to live upon sugar cane and palm trees, have they assumed economic importance or been accused of damaging crops. There can be no doubt that clearing away of forest growth and removal of their natural food has greatly altered their habits. This is strikingly illustrated in the Island of Vieques, lying just east of Porto Rico, where the timber has been practically all removed, and where as consequence the smaller species of rhinoceros beetles, *Strategus titanus* Fab., has become more injurious to sugar cane than in Porto Rico.

THE NAME "RHINOCEROS BEETLE."

The reason for calling the various species of *Strategus* "rhinoceros beetles" is the fact of their having usually, at least in the male sex, one or more large, prominent horns on the fore part of the body. Only the males develop horns, and these vary in size from small tubercles to projections nearly an inch in length, all borne on the thorax. Usually the horns occur in a triangle, one forward and two back, the front horn being the longer, and curved upward (see plate 4, Fig. 1). By means of these horns the powerful male beetles can tear their way easily into mature sugar cane, and even into the solid wood of the coconut palm. The males use the horns also in fighting, and engage often in long battles. The size of the beetles, as well as of the horns, seems to be determined largely by the amount of food that was available to the larva during its period of feeding. At least, in our breeding experiments the best-fed larvæ have produced the largest adults, and in the case of males, those with the largest horns. In no case does a small male have prominent horns, nor a large male reduced horns.

It should be noted that the true rhinoceros beetle, which is a pest of the coconut occuring in Samoa and other Pacific Islands (*Oryctes rhinoceros* Lind.) is more worthy of this name than are our own species, as it bears the horn on the head instead of on the thorax, and is able to wield it with the same upward, ripping motion as does the African and Asiatic mammal from which it is named. As there is, however, no representative genus *Oryctes* in the western hemisphere, the species of *Strategus* have acquired the same popular name.

The true rhinoceros beetle, mentioned above, is perhaps best known as a pest of coconuts in Samoa, where it was introduced some years ago and has since been inflicting great injury to the coconut palms, due supposedly to the fact that its natural enemies were not introduced with it. The species occurs also in India, Ceylon, Java, Sumatra, Celebes, Borneo and the Philippines, and in all of these localities it is injurious to the palms.

A somewhat similar beetle found in the Solomon Islands, *Trichogomphus semilinki* Ritz., is known as the Solomon Island rhinoceros beetle, and is injurious especially to the coconut palm. In this species also, the horn is on the head.

Another related genus, *Pentadon*, also includes beetles of large size with horn or projection on the fore part of body and they are notably injurious to crops. *Pentadon australis*, occurring in Queensland, attacks the stalks of sugar-cane below the ground as do the larvæ of *Strategus titanus* in Porto Rico. *Pentadon idiota* Herbst. (*P. monodon* Fab.) occurs in southern Russia as a pest of corn and various grain and root crops. *Pentadon punctatus* is recorded as a pest of the grape vine in western Europe. Other species of the genus occur as pests in southern Asia and western Africa.

One of the most remarkable beetles of the *Dynastid* group to which *Strategus* belongs is the Solomon Island elephant beetle, *Xylothupes nimrod* Voet. (= *X. gideon* Linn.). This beetle sometimes reached a length of three inches, which is only slightly greater than our larger *Strategus* (*S. quadrifoveatus* Beauv.). The male has two horns, one on the head and one on the thorax, curved toward each other at the tips in such manner that they form a huge clasper which the beetle can close firmly by an upward movement of its powerful head. These horns vary from a fraction of an inch to over an inch in length, in different individuals. Like the rhinocerous beetle of the Solomon Islands, this is an important coconut pest. It is distributed through Java, Sumatra, New Guinea, the Malay Archipelago, and the Solomon and neighboring islands. A closely related species with similar habits, *Xylotrupes australicus*, occurs in Queensland.

In our western hemisphere, a species of rhinoceros beetle, *Strategus anacheoreta* Burm. has been recorded as damaging coconut palms in the island of Trinidad, and the same species occurs also in Cuba, where it doubtless does similar damage.

In both North and South America there are the large so-called

"Hercules Beetles," belonging to the genus *Dynastes*. They are most closely related to the Solomon Island elephant beetle, but have not been recorded as pests.

LIFE-HISTORY WORK ON RHINOCEROS BEETLES.

Researches into the habits and life-cycles of the Porto Rican rhinoceros beetles were begun early in the summer of 1913, at the same time that the life-history work on the May-beetles was begun. In an insectary erected at Santa Rita, on the south coast, were conducted, during the succeeding three years, the studies on the life-cycles of white grubs, which were summarized on page 47 of the Fourth Report of the Board of Commissioners of Agriculture of Porto Rico (San Juan, 1916). In this table it is shown that both species of *Strategus* required about a year for their complete development, the total egg-to-adult period averaging 338 days for *S. titanus* (from 13 completed rearings) and 430 days for *S. quadrifoveatus* (from 2 rearings). Since the date of publication of this table, much additional work has been done on the rhinoceros beetles and more accurate information secured, particularly in the case of the smaller species. The information thus secured, and the detailed life-history studies, are presented here for the first time.

METHODS OF REARING THE BEETLES.

It is a comparatively simple process to rear *Strategus* adults from the egg by carefully observing certain details. The jar in which the female beetle is confined for eggs should be large and contain sufficient earth, and be examined often enough, so that her movements do not destroy the eggs she has laid. It should contain enough wood or fibrous material so that she may enclose her eggs in fiber cells rather than soil, and she should also be supplied with fresh food frequently in the form of cane cuttings. The male should not be confined continuously with the female as he molests her and prevents egg laying. Soil with the female should be sifted and should be damp, but not wet enough to gum up her legs. A six-inch depth of soil in a battery jar six to eight inches in diameter is sufficient.

When eggs are separated from the soil they are best kept in petri dishes, on the surface of moist sifted soil, where the proper humidity can be maintained to allow them to expand naturally, and at the same time their enlargement and hatching may be observed.

As the young grubs hatch they should be kept singly in 3-inch seamless tin boxes containing equal parts of moist, sifted soil and rotted wood. They should be examined at weekly intervals, and

fresh rotted wood supplied as needed. All the earth and wood in the tin boxes should be replenished occasionally to prevent accumulation of mites, which attach themselves in great abundance to the grubs and may so molest them as to cause them to molt imperfectly and sometimes prevent growth, and ultimately cause their death. After the second molt the grub should be transferred to a 4-inch round tin box, 1 inch in height, in which it may be reared to maturity. The mature grubs should be given wood only (and no soil) as they consume it rapidly. Wood of a pithy consistency is preferable. The boxes containing mature grubs should be weighted down to prevent grubs from pushing off the lids and escaping. When the full-grown grub is ready to pupate it forms an elongate, smooth, hard-lined cell. Daily examinations of the box should be made to obtain exact date of pupation and of emergence of adult. Several days pass before the adult becomes hard and begins to dig about in the box.

Both species of *Strategus* grubs thrive well on rotten wood. The smaller species (*S. titanus*) may be reared equally well on dry, half-rotted fragments of cane stalks, on filter-press cake (*cachaza*), or on dry horse or cow manure.

The Sugar-Cane Rhinoceros Beetle.

Strategus titanus Fab.

This species is called the sugar-cane rhinoceros beetle as it is of economic importance only in connection with the sugar-cane crop. The exact extent to which it injures this crop is difficult to determine, since its grubs occur nearly always in company with those of *Phyllophaga* and *Diaprepes*, both of which may exceed the *Strategus* grubs in numbers but are less apt to be observed by one examining the cane field, the *Phyllophaga* grubs because they are smaller and occur deeper in the soil than those of *Strategus*, and the *Diaprepes* grubs because they are well hidden within their tunnels in the underground stalks. Thus damage to a cane field is often blamed upon grubs of this rhinoceros beetle which in fact was due to the work of *Phyllophaga* grubs.

In February and April, 1913, Mr. D. L. Van Dine, formerly entomologist of this Station, visited a cane field in Hacienda Florida at Santa Isabel, near Ponce, on the south coast, where the field manager had reported serious injury by the *gusano de palo viejo*, as the *Strategus* grubs is known locally. Numerous specimens of the grubs of *Strategus titanus* were found in the soil about the plants, and

it was concluded that they were responsible for the bad condition of the cane, which was very yellow and sickly in most of the fields. As one of two *Strategus* larvæ found in the field were attacked by *Metarrhizium* fungus, another visit was made to the field on May 6 and 7 by Mr. T. H. Jones, then assistant entomologist of the Station, to obtain more of the grubs infected with the fungus. On this visit 44 cane stools, were dug up in the same field, to an average depth of a foot and a diameter of 18 inches, with the following results: *Strategus titanus* grubs, pupæ and adults, 16; *Phyllophaga* grubs, pupæ and adults, 315; *Diaprepes* grubs and pupæ, 77. In other words, there was an average but one *Strategus* to each three stools, but an average of 7 *Phyllophaga* and 2 *Diaprepes* to each stool. This clearly demonstrated that *Strategus* grubs, being the more evident, were blamed for the damage in large part committed by the May-beetle larvæ and the root-weevils.

FEEDING HABITS.

In the older records in our files bearing on this species, the observation has been frequently made that grubs of this beetle had damaged cane roots. But these grubs do not eat roots. In fact, grubs confined in sifted soil, destitute of organic matter, have starved when fed only upon young corn roots.

In the field, grubs of *Strategus titanus* are to be found about cane plants, and boring among the underground stems largely because of the large amount of organic matter that occurs in such situations. What damage they cause results entirely from the occasional severing of the underground stalks by the larvæ, together with the fact that their feeding about the bases of plants inadvertently severs a part of the roots. The mature *Strategus* grub is a voracious feeder, and there can be no doubt that when several of them are present in a stool, their activities cause considerable injury to cane plants. But it is an accidental injury, and when unaccompanied by May-beetle and *Diaprepes* attack, by root disease or by severe drought, it could hardly seriously retard the growth of the cane.

On the other hand, if unusual numbers of *Strategus* grubs are present in a cane field and at same time the cane is suffering from other adverse influences such as drouth or disease attack, or perhaps from poor soil and inadequate fertilization, then attack of the grubs may be severely felt.

The adults of this species do not cause any direct injury to cane, though they do bore into the base of the stool for oviposition, and feed occasionally upon the underground stems.

Besides Porto Rico, this beetle has been recorded as occurring in Cuba, Jamaica and the Virgin Islands. It has also been collected by the writer in Vieques and in Santo Domingo.

In Porto Rico its occurrence is general, though it seems to be considerab'y more abundant in the drier than in humid districts, and all records of its injury to sugar cane come from the Aguirre, Ponce and Guánica districts of the south coast. Dozens of the grubs were collected in manure heaps in coconut plantations near San Juan and Río Piedras, where they were mistaken for the larvæ of the coconut beetle (*Strategus quadrifoveatus*). But it has not been obsaved as a pest of either coconut or cane in the humid section of the Island.

This and the coconut rhinoceros beetle find their natural home in decaying forest trees and stumps, and from such a habitat they have gradually become pests of sugar cane as result of the clearing away of the timber. Perhaps it is the fact that much timber yet remains in the humid sections of the Island that prevents this beetle from becoming a cane pest there. The heavier clay soils of these regions may also affect its attack on cane. It prefers timber land to cane fields, as the writer has collected many dozens of the beetles and their grubs in the wooded hills above Santa Rita at a season when very few were being taken in the cane fields.

This beetle has become firmly established as a cane pest in the coast district lying between Aguirre and Fortuna, east of Ponce. There are many records of injury to sugar cane by the grubs in this section. Mr. Van Dine on February 24, 1912, in some cane fields at Central Aguirre found 48 grubs dug from 7 *cepas* (stools), an average of 7 grubs to the stool—enough to cause serious injury to the cane, in view of the immense voracity of these large grubs. Conditions very similar to this have been found to exist at Hacienda Florida, near Santa Isabel, at Hacienda Amelia, Central Fortuna, and also in the Island of Vieques.

In Vieques during periods of drouth, damage from the grubs of *Phyllophaga*, as result of their trimming the roots, becomes accentuated, and the same drouthy conditions also drive the May-beetle grubs deeper into the soil, so that when the cane stool is pulled up and examined, only the large *Strategus titanus* grubs are encountered, and they are naturally blamed for the injury. In a careful examination of many stools of cane an average of 29 grubs and pu-

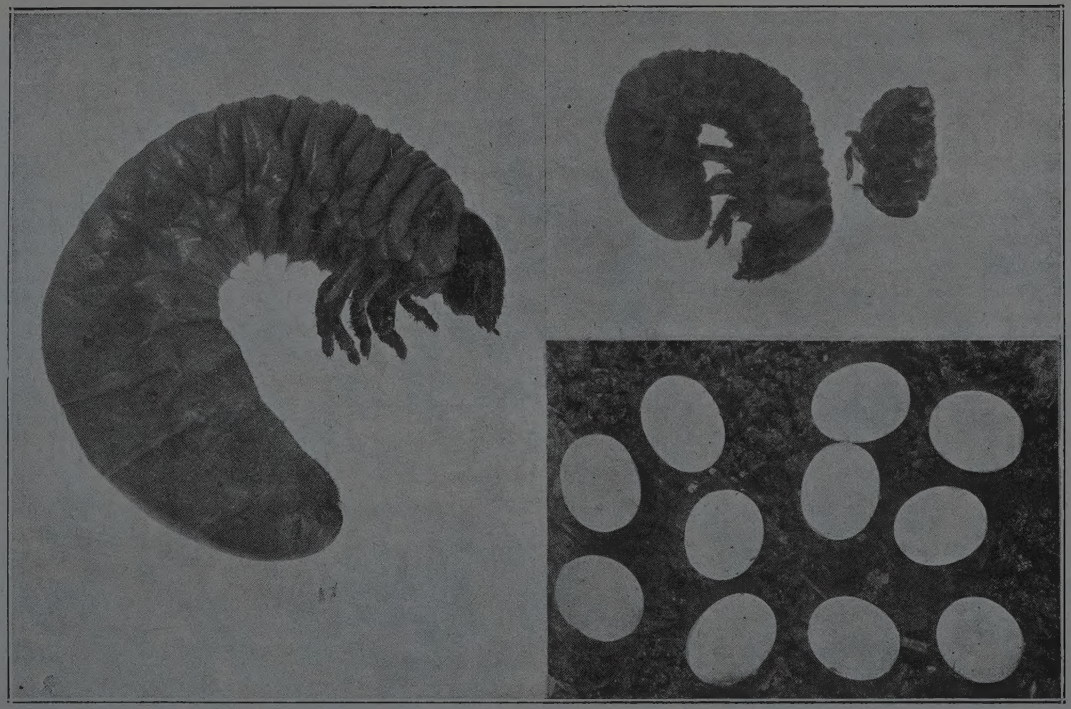

PLATE 1.—**Fig. 1.**—**Fully grown third-instar grub of** *Stratægus titanus*. (2 ×).
Fig. 2.—**Third-instar grub of** *Stratægus titanus* **just molted, showing skin of second instar just shed.** (1½ ×).
Fig. 3.—**Eggs of** *Stratægus titanus*. (3 ×).
(Note that the heads of the grubs of Fig. 1 and Fig. 2 are of approximately the same size.)

pæ per 100 square feet were found, of which 25 were of *Phyllophaga* and 4 of *Strategus*.

On the property of the Guánica Central, where many dozens of bushels of white-grubs [1] are collected annually in the cane fields at plowing time by the laborers, the writer has noted that an average of less than five per cent of the grubs belongs to this species. The great majority belong to the real root-trimming species of May-beetle (*Phyllophaga vandinei* Smyth), which causes most of the damage to cane in this region.

PREVIOUS WORK ON THE SPECIES.

The injury to sugar cane caused by the grubs of this species was first recorded in Porto Rico in 1913 by Mr. Van Dine, on pages 42 and 43 of the Third Annual Report of the Station, though the identification was at that time uncertain.

The injury from the species is mentioned by Mr. Jones in an article in the *Journal of Economic Entomology* (Vol. 8, No. 6, Dec., 1914, pp. 461–463), by the writer in the first report of the South Coast Laboratory in the Third Report Bd. Comm. Agr. of P. R., 1913–14, pp. 40–53, also on page 49 of the Fourth Report Bd. Comm. Agr. of P. R., 1914–15, giving the life-cycle from eggs to adult.

DESCRIPTION OF THE ADULT.

This species can be distinguished from *S. quadrifovatus* by its smaller size, less highly polished surface of body, and by the presence of distinct longitudinal rows of punctures on the elytra, which are absent in the larger species. The males may be readily distinguished from those of the other species by the fact that the anterior horn has a tendency to divide at the tip into two short prongs. (Plate 3, Fig. 1.)

LENGTH OF LIFE-CYCLE.

The life-cycle of the sugar-cane rhinoceros beetle covers approximately one year. The minimum egg-to-adult period, among the 44 reared adults, was 271 days, or just 9 months, and the maximum was 429 days, or practically 14 months. The average normal egg-to-adult period for 44 individuals (of which 14 were male, 18 female, and 12 of undetermined sex) reared in tin boxes was 341 days, or practically 11¼ months. The other three-fourths months is about what is normally required as pre-oviposition period; that is, the

[1] See Jour. Dept. Agr. of P. R., Vol. 1, No. 2, page 69.

time elapsing from emergence of the adult from the pupa to the laying of the first fertile egg. If we add to the average egg-to-adult period of 341 days (for the 44 reared adults) the average pre-oviposition period of 22 days it gives an average normal life-cycle of 363 days, or almost exactly one year.

As a control on the individual rearings of beetles made in the tin boxes, considerable numbers of them were reared in cages consisting of screened boxes placed over the soil outdoors. In these the beetles were bred "en masse," a few females being introduced at one time and a week or so later all removed. Thus only the date of egg laying and the final date of emergence of the adults could be observed, the immature stages being meanwhile undisturbed. It was found that the average length of time required for passing of all immature stages in such cages did not vary more than a few days from that secured by the rearing of grubs in the tin boxes.

The average egg-to-adult period calculated by adding together the average lengths of the three immature stages—egg, three instars of the larva, and pupa—amounts to 354 days, which is in excess of the average period calculated direct from the 44 grubs that reached maturity because it includes the rearings of grubs that became diseased with *Metarrhizium* and *Micrococcus*. It is known that attack by either of these diseases somewhat increases the length of the instar just preceding that in which fatality occurs.

THE EGG STAGE.

Description.—The egg of *Strategus titanus* is opaque and pearly white in color, oblong-oval in shape and round in cross-section. Between the date of laying and the date of hatching it swells greatly in size, and becomes more nearly globular. When first laid the eggs average 2⅞ mm. to 3mm. in width by 3½ mm. to 3¾ mm. in length. When fully expanded, and just before hatching, the eggs average in size 4 mm. to 4½ mm. in width by 5¼ mm. to 5⅜ mm. in length. (See Plate 1, Fig. 3.)

The average length of the egg stage, calculated from the rearing of 207 eggs, was found to be 17½ days. The minimum length of egg stage was 15 days (in August), the maximum, 19 days (in December).

As is the case with the May-beetles, the rhinoceros beetle lays its eggs singly, in hardened, spherical cells of earth or fiber that are smooth and symmetrical on the inside, and are from two to three times the diameter of the newly deposited egg. The favorite place,

apparently, for depositing of the eggs, is among the chewed-up and torn fiber in which the adult beetle has been tunneling. Often the eggs are laid inside the buried cane stalks which she has hollowed out in her feeding.

THE LARVAL STAGE.

Description.—The larva of this species is an opaque, yellowish-white to bluish-white "white-grub." In mature larvæ the posterior portion of the body is usually quite dark because of the large amount of blackish woody matter or humus which it contains. The grub has six prominent legs, close together on the ventral side just back of the head, and these are not used for crawling, but merely to assist the grub to move about in its subterranean tunnel. The body is bent, the ventral side inward, and is poorly adapted for crawling, though the grub can straighten its body and crawl over the surface of the ground quite rapidly. The head of the grub is dark brown and chitinous, pitted with many punctures and furnished with very strong mandibles for chewing up woody tissue. The white body is sparsely covered with very short, fine, reddish-brown hair, which is quite inconspicuous. On the legs the hair grows slightly longer and thicker, giving them a brownish color. (Plate 1, Figs. 1 and 2.)

The length of the larval stage, calculated from 53 larvæ that passed the period from egg to pupa successfully in confinement, was 303½ days, or practically 10 months. The minimum larval period of these 53 larvæ was 229 days (7½ months); the maximum 391 days (13 months).

In common with other white-grubs, it molts three times during its life before changing to a pupa, and the periods spent between the molts are called larval instars. During the instars the body of the grub grows at a fairly constant rate, at least until nearly full grown, but the head and legs do not increase perceptibly in size. These latter expand at each molt, then remain without growth until the following molt.

First Instar.—The first instar of the grub is the period comprised between the dates of hatching of the egg and the first molt. During this instar the grub makes its greatest growth, though this instar is considerably shorter than either the second or third instars. The average length of the first instar of 115 grubs was 40½ days; the minimum, 24 days; the maximum, 72 days. From the hatching of the grub to the first molt it increases in length from 8 to 25 milimeters. The average width of head of 20 grubs of first instar was 3.54

mm.; the minimum, 3.25 mm.; the maximum, 3.9 mm. The first-instar grub is able to subsist and grow with no more organic matter present than the normal humus in black soil. Toward the end of the instar, however, it begins to devour rotten wood or cane stalks when these are available.

Second instar.—The average length of the second instar of 67 grubs was 72 days, or not quite two and a half months. This is almost double the length of the first instar. The minimum length of time spent in this instar by any grub was 43 days; the maximum, 85 days.

The rate of growth of the grub during the second instar is shown by the following table:

Growth of Second Instar Grub.

Number of grubs averaged	Age of grubs	Average length of body	Average width of head
16	Under 1 week	25¼ mm.	5.64 mm.
34	1 to 5 weeks	32 mm.	5.84 mm.
36	5 to 9 weeks	40¾ mm.	6.07 mm.
5	Over 9 weeks	45 mm.	6.24 mm.

Third Instar.—It is during the third instar that the grub makes its most astonishing growth. However, all of this growth is accomplished during the first two or three months. During the remaining three to four months, preceding pupation, the grub grows very little, though there is an increase in weight due to the constant building up of fatty tissues in its body. (Plate 1, Figs. 1 and 2.)

The average length of the third instar, calculated from 55 grubs, was 199 days, or 6½ months. The minimum length of third instar for any grub was 137 days (4½ months); the maximum, 282 days (9¼ months).

FEEDING HABITS OF THE LARVA.

The sugar-cane rhinoceros beetle has acquired the habit of attacking sugar cane within comparatively recent years. In the dense woody growth of the base of a large cane plant the larvæ find conditions favorable to their development, and the adult finds an abundance of food material in the living cane stems.

The grubs show a strong preference for the rotted stems in the cane stool, and do not ordinarily attack the living stems. However, when the grubs are abundant, the portions of dead stem remaining in the stool from a previous ratooning may be entirely consumed by

them before they reach maturity, and in that case they do not hesitate to attack the underground portions of the living stems. Grubs have been observed which had entirely severed growing cane stalks underground, and then tunneled upward within the stalk, sometimes for a distance of several inches, and pupæ have been found within the tunneled base of the stalk underground.

The grubs of this beetle show a preference for rotting wood, and are most frequently encountered about stumps in the fields, at the bases of fence posts, and in piles of stable manure.

THE PREPUPAL STAGE.

When the rhinoceros grub has reached maturity it ceases feeding and proceeds to make, out of the fiber and soil surrounding it, a smooth oblong cell in which it can pupate; that is, transform to the dormant, resting condition, which is called the pupa. The pupal cell is oblong, two or three times the length of the pupa, and not quite double its width. It is usually made near where the grub ceases feeding.

The mature grub becomes inactive or even very sluggish for some days or weeks before pupation. The first symptom of approach of the pupal period is a slight yellowing of the grub in color, the skin becomes flabby and wrinkled, and the grub feels soft to the touch where formerly it was firm. The grub lies on its back, with the head and caudal part of the body bent upward sharply, not in a rounded curve as formerly. The legs are drawn close together and held upward stiffly. The grub is motionless and does not move even when touched. It remains in this condition for a period almost equal to the pupal stage.

During the prepupal stage the larva is especially susceptible to the attack of fungus or bacterium, or of such pests as mites and nematodes.

THE PUPAL STAGE.

At the end of the prepupal stage the larva sheds its skin and changes to a pupa, or nymph, which is at first white but changes to brown within a few hours. (See Plate 2, Fig. 1.) The pupa lies motionless in the cell, except that it turns over occasionally and lies with ventral side down at intervals. The legs of the adult are clearly indicated on the pupa, but end in rounded knobs where the feet are to form.

The length of the pupal stage averages 24 days (3½ weeks). The minimum pupal period was 22 days; the maximum 29 days.

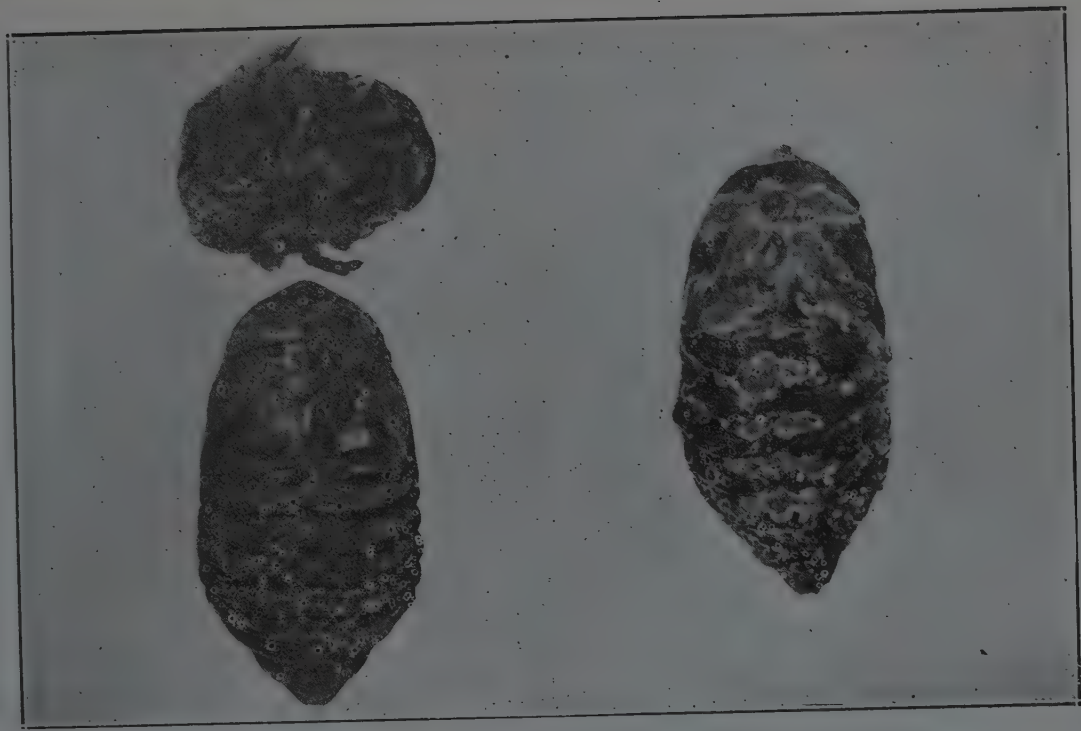

PLATE 2.—Fig. 1.—Pupa of *Stratægus titanus*, with shed skin of thid-instar grub above. (2 ×).
Fig. 2.—Pupa of *Stratægus titanus* killed by the fungus *Metarrhizium anisopliæ*. (2 ×).

EMERGENCE OF THE ADULT.

The adult is entirely white in color when first emerging from the pupal skin. The head and thorax and the legs are the first to turn brown, the elytra turning more slowly, requiring several days before they have reached complete hardness.

Since rhinoceros beetles do not burrow deeply in the soils to pupate, as do the May-beetles, heavy rains to soften the soil are not necessary before they can emerge from the pupal cell. They become active within a week after issuing from the pupa, and at once dig their way to the open. This means that while the egg-to-adult period of the *Strategus titanus* averages 11 months as compared with 9 months for the same period in the sugar-cane May-beetle (*Phyllophaga vandinci* Smyth), the period spent in the pupal cell after issuing from the pupa is so much shorter than in *Phyllophaga* that the complete life-cycle differs very little from that of the May-beetle.

FEEDING HABITS OF ADULTS.

Unlike the adult May-beetles, the rhinoceros beetles do not feed upon foliage. Their food consists largely of the green parts of woody plants and young trees, and perhaps to some extent of the rotted wood or other material which the larva eats. They rarely destroy cane, as is the case with the coconut rhinoceros beetle, and this is only incidental to their penetration into the cane stool to lay their eggs. Injury to the buds of cane supposed to be caused by this beetle has been called to the attention of the writer, but most often such work is due to the hard backs, *Ligyrus* or *Dyscinetus*.

HABITS OF FLIGHT.

The adults of *Strategus* are very strong fliers, and cover a considerably larger range of territory in their flight than do the May-beetles. However, because of their very different feeding habits, the beetles do not come forth nightly to take flight, but may occasionally remain a number of days in their burrows in the cane stool, or in a rotten stump. The females fly less often than the males, and the presence of one or more females in a cane stool may cause the gathering of a number of males, new ones arriving each night. This habit of the males gathering where females are present has been observed in the case of a screened cage in which the beetles were being reared from manure.

The beetles fly with a heavy buzzing sound, very fast in the ear-

lier hour of dusk, but slower as darkness approaches and closer to the ground, in search of suitable breeding places.

Adults of both sexes come to light, and have been collected during almost every month of the year, but most commonly between April and September. They never come in large numbers to light, and the collection of a dozen individuals in a whole summer, even at strong light, is exceptional. The use of light traps as a means of control gives no promise of success.

COPULATION.

Copulation of the adult beetles may take place at any time, and usually within the concealment of the beetle's burrow. The male beetles exhibit great strength and endurance. They are exceedingly amorous, and will engage in long combat with any other male that approaches a female. At such times the horns are used to best advantage, and the possessor of the larger horn, which is also in every case the larger beetle, is the victor, and sends its adversary rolling time after time.

As the male approaches its mate it produces a loud squeaking noise that may be heard for a long time after the beetle enters the burrow and passes out of sight.

PRE-OVIPOSITION PERIOD.

The length of the pre-oviposition period for this species, the average of 5 females, was 24 days, the minimum being 20 days and the maximum 27 days. When added to the egg-to-adult period of 431 days, this makes a total life-cycle for the species of exactly one year.

A freshly issued pair of beetles confined together on September 1st was observed in coitu on September 18th, and the first egg was laid September 28–30.

OVIPOSITION.

The average length of life for 11 females confined to observe oviposition was 37½ days (5 weeks), and the maximum 93 days (3 months). The average number of eggs per female was 13, the maximum number 43. The average estimated length of oviposition period was 8 days, the maximum 21 days, the minimum 1 day. Usually oviposition was continuous from the day that it began, but in 3 cases it was interrupted by short periods of a few days, during which time there was no egg-laying.

In a recent number of THE JOURNAL OF THE PORTO RICO DEPARTMENT OF AGRICULTURE,[1] page 141, the writer has recorded briefly the natural enemies of the two species of rhinoceros beetle occurring on the Island. Among these, the mongoose is very probably the most important. As a result of studies made by Mr. C. B. Williams, in Trinidad, it has been shown that beetles, particularly *Sacrabacidæ*, constitute a portion of the food of this animal, which enjoys such bad repute in all the islands into which it has been introduced, due to its attacks on poultry and the native birds.

The Porto Rican blackbird (*Holoquiscalus brachipterus*) is most efficient in destroying the larvæ when they are turned up by the plow, particularly the immature larvæ. The writer has seen several of these birds attack and eat a full-grown grub of this species.

The rhinoceros beetle has no insect enemies.

There are at least two species of mites commonly found on the adult beetles. One of these is sluggish and does not move about over the body of beetles. It is doubtless a fungous-inhabiting mite that uses the beetle merely as a means of transportation. The other mite, however, is a true parasite of the beetle and may be found upon it in all stages. It runs about very actively among the hairs over the beetle and gathers in numbers along the sutures on the underside to feed. The immature stages are pale, yellowish white, while the mature mites are brown. When a beetle dies, the mites at once leave it and crawl about the soil very actively, at once attaching to any living *Strategus* they may encounter. The mature mite is over a millimeter in diameter—quite large for a beetle parasite. The species has not been determined.

Another mite, of very different form, is apparently parasitic on the eggs of *Strategus*. This is a very slow-moving and sluggish mite, seven-eighths mm. to 1 mm. in diameter, pearly white with brown markings, rather thick and of a truncated oval shape. It is an inhabitant of the egg cavities made by the *Strategus* beetle during oviposition and feeds upon the egg, ultimately causing its death. The mite has not been determined.

The grubs in confinement are subject to a bacterial disease which produces shining black hardened areas on the body, legs or head, which often spread so as to result in the death of the grub. This disease is caused by the bacterium *Micrococcus nigrofaciens*, which also attacks the smaller May-beetle grubs. No diseased grubs have

[1] List of Insect and Mite Pests of Sugar Cane in Porto Rico.

been collected in the field, but grubs which were healthy when collected often become diseased in confinement.

The green muscardine (*Metarrhizium anisopliæ*), is extremely virulent in its attack upon this beetle, both in the adult and the immature stages. The stage most susceptible to attack seems to be the pupa (Plate 2, Fig. 2.); that least susceptible, the egg.

The first green muscardine was found in Porto Rico when Mr. Van Dine noted a grub of this species attacked by it on Hacienda Florida, at Santa Isabel, on February 1, 1913. The diseased grub was referred to Mr. J. R. Johnston, the pathologist of the Station, and the fungus determined as *Metarrhizium anisopliæ*. On May 6 and 7 Mr. Jones visited the field and made a thorough examination of the soil surrounding 44 stools of cane, and found, of 8 larvæ, 2 pupæ and 6 adults of this species collected, that 4 larvæ (50 per cent) and 2 pupæ (100 per cent) were diseased with *Metarrhizium*. Among the number of *Strategus* grubs which he brought back to Río Piedras to rear, the disease had developed by July 3d in 2 more larvæ.

CONTROL.

Use Correct Planting System.—One thing which greatly encourages the attack of grubs of this beetle as well as other white-grubs, in sugar-cane plantations, is the method of planting cane by which the new furrow is broken midway between the two old furrows, when cane is to be replanted and all the old rattoon stubble left in the field, undisturbed. Not only are all grubs or pupæ in the cane stools allowed to mature, but if there are young stages present below the third instar, which have most of the feeding to do yet, these merely migrate from the stubble to the new plant cane and begin feeding on it. In all circumstances the old cane should be plowed open down the row, and the grubs thus exposed gathered and destroyed.

Avoid Excess of Organic Matter.—As *Strategus* grubs feed entirely upon organic matter, the addition of stable manure, filter-press cake, bagasse, or any other organic fertilizer should be avoided in any fields or parts of fields subject to attack of rhinoceros beetle grubs. Even an excess of dead cane stubble and dry stalks should be avoided by piling and burning these after the plowing.

Use of Poison Bait.—Grubs of the rhinoceros beetle may be very successfully poisoned by means of a poison bait consisting of some organic fertilizer, palatable to them, to which has been added a small amount of some arsenical. Stable manure, bagasse or filter-

press cake that has been broken up fine may be used. The arsenical poison should be stirred thoroughly into a large bucket of water, and this is then sprinkled over the organic fertilizer by means of a sprinkling can. Two pounds of white arsenic (arsenic trioxide) or Paris green, or four to five pounds of lead arsenate, calcium arsenate or zinc arsenate may be used to each hundred pounds of manure, bagasse or *cachaza*. The poison bait thus made may be thrown in small handfulls around the newly planted cane before it is covered, or may be thrown broadcast in the field before the final plowing. Or it may be thrown about the stools and covered with trash. The grubs eat it and are killed in large numbers. This control method serves also for protection against hard-backs, but does not have any effect on the root-trimming grubs of the May-beetle. Pen manure lying in piles near the cattle pens can be poisoned in the same way and many grubs killed.

Manure Trap Piles.—Where there are local sections of cane fields attacked by these grubs, it is possible to attract the beetles and grubs in large numbers by placing manure heaps at intervals along the border of cane fields. At regular intervals of once a month or once in two months these should be spaded over carefully and all the grubs and beetles found in them destroyed. However, if such piles are abandoned and not visited regularly and the grubs destroyed, they become a menace rather than a benefit because of the large number of beetles that mature in them

The Coconut Rhinoceros Beetle.

Strategus quadrifoveatus Beauv.

This beetle secures its name from its habit of damaging the coconut palm. As a pest of sugar cane it is of small importance, although the adults have been taken a number of times injuring cane. A few such instances have been recorded by the writer[1] in previous publications of this Station.

As a pest of the coconut palm this insect is possibly responsible for more injury than is generally noted, because coconut plantations, once set out, are usually not further cared for until they mature, so that the occasional loss of a few trees in the midst of hundreds of acres of them is not looked upon generally with concern.

[1] Third Rept. of the Board Comm. of Agr., page 44, Fourth Report, page 49, and Ann. Rept. for 1917–1918, page 123.

PLATE 3.—Fig. 1.—Male adult of *Stratægus titanus*, showing anterior thoracic horn divided at tip. (2 ×).
Fig. 2.—Underside of female adult of *Stratægus titanus* killed by the fungus *Metarrhizium anisopliæ*. (2 ×).

This species has been recorded from Santo Domingo and Haiti, in addition to Porto Rico. The mature larvæ have been found in rotten stumps at Higueral, Santo Domingo, near La Romana, but no adults. In Porto Rico the species is very common, and is distributed over the entire Island. It doubtless occurs also in Vieques, Culebra and Mona Islands.

The insect differs from the preceding species in that the grubs have not acquired the habit of attacking sugar cane, and attempts to rear them in confinement on any other material than rotting wood or coconut fiber have resulted in failure.

Only the adults injure sugar cane, and usually several are found in one stool while no other stool near by is attacked. The males always predominate, and very often there is but a single female present among a half dozen or more males taken from one stool. It seems probable that the female alights among the cane and that the males are attracted to her. Having lit in the cane, the beetles bore into the base of the stalk for the succulent juice. The beetles enter near the ground and bore upward, sometimes excavating a tunnel eight inches to a foot or more in length. The cane, weakened by the large size of the excavation in it, is soon blown over by the wind. The work is so conspicuous as to always command the attention of any worker in the field, and to cause some apprehension. Yet in no case have more than one or two stools been attacked on a single plantation in an entire season, so that the injury is insignificant in extent compared with that caused by the grub of the sugar-cane rhinoceros beetle.

It is in the coconut plantation that this beetle causes its great damage, and this will be described later.

PREVIOUS WORK ON THE SPECIES.

The writer first published a brief note on the injury to sugar-cane by this species in the Third Report of the Board of Commissioners of Agriculture, page 44. The species was not accurately determined until the following year, when another note on the injury caused by the adults to cane was published (Fourth Report of the Board, page 49), and the life-cycle of the species was given (page 47). On pages 123 and 124 of the Annual Report of the Station for 1917–1918 the writer gives a short account of the beetle and its injury.

This species is also treated briefly in a recent number of this JOURNAL,[1] along with *Strategus titanus* and other cane pests.

DESCRIPTION OF ADULT.

The adult of the coconut beetle may be at once separated from that of the sugar-cane rhinoceros beetle by its much larger size and more highly glossed surface, and by the absence of the longitudinal rows of punctures present in the smaller species. In the male of this species, the anterior horn is never divided at the tip, where in the other species it shows a strong tendency to divide into two short prongs. (Plate 4, Figs. 1 and 2.)

LIFE-HISTORY WORK.

Unfortunately, a much smaller number of this insect has been successfully reared through all the instars to the adult than is the case with *S. titanus*. This is due partly to the greater difficulty experienced in rearing these grubs, as they refuse any food but rotted wood or coconut fiber, and do not thrive well on the latter. Even the rotted wood must be of proper consistency to be acceptable to the grub.

LENGTH OF LIFE-CYCLE.

For two individuals which were reared from egg to adult, the average egg-to-adult period was 430 days (14 months).

The pre-oviposition period was not determined, as neither of the two reared adults was kept alive for the eggs. However, if the pre-oviposition perior is the same as that for *S. titanus*, 24 days, this added to the egg-to-adult period of 430 days makes a total life-cycle of 454 days (or 15 months). This is probably somewhat in excess of the average for the species.

THE EGG STAGE.

Description.—The egg of this beetle is similar in appearance to that of *S. titanus*, but somewhat larger in size. When first laid it varies from 3.1 mm. to 4 mm. in length by 3 mm. to 3.35 mm. in width. When fully expanded and shortly before hatching it varies from 5 mm. to 5.2 mm. in length by 4.5 mm. to 4.6 mm. in width.

The average length of the age stage was found to be 20 days, the minimum 17 days, the maximum 22 days.

[1] The Insect and Mite Pests of Sugar Cane in Porto Rico, Jour. P. R. Dept. Agr., Vol. III, No. 4, p. 141.

The larva of this species differs from that of the preceding mainly by its larger size and by the broader head. In fact, the head of the grub is enough larger than that of *S. titanus* to make it possible to distinguish it readily from the other in any of the instars by measuring the head. The average length of the larval period for this species was 383 days (12½ months).

First Instar.—The average length of the first instar of this species, from a rearing of 8 grubs, was 39 days. During this instar the grubs increase from 10 mm. to 28 mm. in length, and the width of the head varies from 3.4 mm. to 3.6 mm.

Second Instar.—The length of this instar, calculated from the rearings of 9 grubs, was 71 days. As a result of the rapid growth of the larva that takes place during the second instar, it increases in length from about 28 mm. to 55 mm. before molting to third instar. The head varies in size from 6.6 mm. to 7.3 mm.

Third Instar.—The last larval instar, according to the breeding experiments, covers the very long period of nine months. Whether the larval period of the two individuals that were successfully reared to adults in confinement was unduly prolonged as a result of the artificial conditions of their environment, or whether they represent the normal period for the species, can only be determined after additional rearing work with the insect. There seems no reason to believe that the confinement of the grubs lengthened or otherwise altered the larval period in the case of this species when it did not do so with the other *Strategus.*

The average length of the third instar, calculated from two grubs, was 275 days. During this instar the grub increases in length from about 50 mm. to 85 mm., and the head varies from 11.5 mm. to 12.5 mm. in width (being from 1 to 2 millimeters wider than that of *S. titanus.*)

The heads of grubs, presumably of this species, collected in rotten palm trees in Santo Domingo by G. N. Wolcott, measured in width: first instar, 3.5–3.7 mm.; second instar, 7.5 mm.; third instar, 14.3 mm.

FEEDING HABITS OF LARVA.

This grub thrives only upon decayed wood and partly rotted coconut fiber, and refuses to feed upon manure or other organic fertilizer. It is never encountered in the cane fields except around the bases of old stumps.

In one experiment made by the writer a dozen adults of this

PLATE 4.—Fig. 1.—Male adult of *Stratægus quadrifoveatus* (1½ ×).
Fig. 2.—Female adult of *Stratægus quadrifoveatus*. (1½ ×).

beetle, of both sexes, were put into a large screened rearing cage, three feet square and six feet high, which covered a large stool of half-grown cane planted in the field. Within two weeks the beetles had bored extensively into the bases of two stalks of cane, killing both, and had injured other stalks at their bases.

Two months later the cage was removed and the cane stool and soils dug up and examined to a depth of a foot. The beetles were all dead and had decayed, and if eggs had been laid, there were at least no sign of grubs in the soil. This demonstrated that eggs deposited in such material do not mature, or that the grubs of this insect cannot live upon cane stalks or stubble.

THE PRE-PUPAL AND PUPAL STAGES.

The descriptions of the pre-pupal and pupal stages of *S. titanus* apply equally well to *S. quadrifoveatus*. The average length of the pupal stage (for 2 pupæ) was 27 days.

In size, the pupa as a fourth larger.

FEEDING HABITS OF THE ADULT.

The adult eats the succulent tissue of woody plants and trees, into which it bores by means of its powerful barbed legs and mandibles. It is remarkable how these beetles can tear their way into the tough, woody stem of a living coconut palm, or a mature cane tsalk. So powerful is the beetle that it is almost impossible to hold one in the naked palm without suffering lacerations of the skin.

This beetle differs from the true rhinoceros beetle of Samoa (*Oryctes rhinoceros*) in that it does not enter the stem of a coconut palm high up among the leaves, as does that insect. It does, however, very often bore into half-grown to mature coconut palms at the level of the ground, even though the palm is thriving and healthy. The writer has seen, near Río Piedras, several coco palms of large size blown over by the wind, during a hurricane, that showed extensive cavities at their base. The cavities are doubtless made in all cases by the beetle and never by the grub. In no case have the larvæ been found in these cavities in living palms.

The greatest damage to palms from this beetle does not come from its boring into mature or half-grown trees, but from its havoc to trees under two years old by boring upward, from the central tissue of the young palm. Much trouble from this source has been experienced by all coconut plantation owners, and some of them replant yearly from one to five per cent of all nursery trees from this cause. One beetle is sufficient to kill a young palm in a single

night, though it does not usually leave the same palm for some days. In a season's time, however, one beetle may kill a dozen or more palms. For this reason, each beetle that is caught and killed early in the season may mean the saving of several young trees; and realizing this, the plantation owners set boys to work catching them as soon as the flight begins, and pay as high as five cents per beetle.

FLIGHT AND COPULATION.

These have been described for the preceding species, and the habits of the adults of the two species, as regards time and nature of flight, copulation, etc., are very similar, and differ only in the matter of feeding habits.

OVIPOSITION.

The pre-oviposition period of this beetle has not been determined by experiment, but probably exceeds that of *S. titanus* by a few days.

NATURAL ENEMIES.

These are the same as for *S. titanus*, and have been discussed under that species.

Some mites, determined by Dr. H. E. Ewing as *Tyrogryphus heteromorphus* Felt, were found on grubs collected in rotten palm trees in Santo Domingo by G. N. Wolcott. This mite is a fairly common species in the United States and has been reported as injuring the roots of carnations in Massachusetts, but its food habits have not been extensively studied.

CONTROL.

As a cane pest, this beetle is of slight importance and the control need scarcely be considered. As a coconut pest, however, the insect is a real menace, and it behooves any owner of a young coconut plantation to take active steps to reduce the number of the beetles.

Prevention of Attack.—Several methods of protecting the young palms against attack of the beetles have been suggested, but the author has not had opportunity to try out any of these on a large scale. Mr. S. V. Lippitt claims to have obtained complete protection of his young plants by putting plenty of rock salt around each tree.

If it is true that the rotting coconut husk of the germinating nut first attracts the beetles as a place to lay its eggs, and that from

this from this it bores upward into the fleshy center of the young tree to secure food, then it may be possible that the treatment of the nut and husk, before planting, with some very strong repellent such as carbolinium or crude petroleum, would protect the young tree from the attack of the beetle until it had reached sufficient size to escape danger.

Catching the Beetles.—A very safe, sure, and inexpensive way to get rid of the beetles is to have them collected by small boys provided with hand nets similar to butterfly nets, but made of stronger material. As the beetles fly through the coconut grove at dusk they may be captured by a boy provided with such a net. Each beetle captured means not only the saving of one or several young coco palms, but also a decrease in numbers in the next generation of beetles. The beetles should be killed and not allowed to escape, as was done on one coconut plantation visited by the writer.

Removal of Breeding Places.—The larvæ of this beetle breed only in decayed or rotting wood logs and stumps. Such material should be collected into piles and burned. Or it should be accumulated into piles and then turned over and examined at intervals once a month or once in two months, and all grubs found in it collected and destroyed, or fed to hogs. The number of large grubs that may be gathered in this manner will astonish the average coconut grower, if he has them collected.

If the old wood and rubbish in a plantation is gathered into piles, but no attempt made to destroy it nor to have it turned over and examined regularly for the grubs, it becomes more of a menace than when scattered about the grove, and becomes a favorable breeding place for the grubs, from which beetles will issue in large numbers every year.

Poisoning Grubs.—While no experiments have been made in order to test the practicability of control by poisoning, it is possible that the grubs of the rhinoceros beetle may be poisoned successfully. Where the coconut husks are piled about the bases of trees in a plantation, turning over or raking aside of these would be expensive, but by sprinkling them thoroughly with a liberal amount of water in which has been mixed Paris green at the rate of two pounds per hundred gallons they could be made permanently poisonous to the grubs.

PUBLICATIONS OF THE YEAR (1919–1920).

(Published or in Press.)

1. Annual Report of the Insular Experiment Station of the Department of Agriculture and Labor of Porto Rico 1918–19. (E.)
2. The Journal of the Department of Agriculture of Porto Rico, Vol. III, No. 3. The Mottling or Yellow-Stripe Disease of Sugar Cane, by J. A. Stevenson. (E.)
3. The Journal of the Department of Agriculture of Porto Rico, Vol. III, No. 4. Yellow-Stripe Disease Investigations (Progress Report), by F. S. Earle, C. A. Figueroa, E. D. Colón, F. A. López Domínguez, J. Matz and E. G. Smyth. (E.)
4. The Journal of the Department of Agriculture of Porto Rico, Vol. IV, No. 1. Root-Disease Investigations, by F. S. Earle and J. Matz. (In press.) (E.)
5. The Journal of the Department of Agriculture of Porto Rico, Vol. IV, No. 2. The White Grubs Injuring Sugar Cane in Porto Rico. The Rhinoceros Beetles, by E. G. Smyth. (In press.) (E.)
6. Bulletin No. 19. The Resistance of Cane Varieties to Yellow Stripe or the Mosaic Disease, by F. S. Earle. (E.)

   Boletín No. 19. (Edición española.) La Resistencia de las Variedades de Caña a la enfermedad de las Rayas Amarillas o del Mosaico.
7. Boletín No. 20. Insecticidas y Fungicidas, por I. A. Colón. (S.)
8. Boletín No. 21. Abonos (1918–19), por F. A. López Domínguez y R. Vilá Mayo. (S.)
9. Bulletin No. 22. Eradication as a Means of Control in Sugar-Cane Mosaic or Yellow Stripe (The Year's Experience with the Method), by F. S. Earle.

   Boletín No. 22. (Edición española.) La Extirpación del Mosaico de la Caña como Medio de Represión, por F. S. Earle.
10. Bulletin No. 23. Plant Inspection and Quarantine Report (1918–19), by E. G. Smyth. (In preparation.) (E.)
11. Circular No. 17. Recomendaciones sobre el Cultivo de la Caña en Puerto Rico, por F. S. Earle. (S.)
12. Circular No. 18. Extirpación de la Garrapata, por J. Bagué. (S.)
13. Circular No. 19. La Preparación de Abonos Mezclados por el Agricultor, por F. S. López Domínguez. (S.)
14. Circular No. 20. La Gomosis de la Caña, por J. Matz. (S.)
15. Circular No. 21. El Cólera del Cerdo, por J. Bagué. (S.)
16. Circular No. 22. El Mosaico de la Caña o Matizado, por F. S. Earle. (S.)
17. Circular No. 23. Variedades de Caña, por F. S. Earle. (S.)
18. Circular No. 24. La preparación de la Disolución Arsenical para el Exterminio de la Garrapata, por F. A. López Domínguez. (S.)
19. Circular No. 25. El Mal del Guineo, por J. Matz. (S.)

(E.) means English only.
(S.) means Spanish only.